Residual radioactivity in food samples after accident in Chernobyl

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Abstract

In this paper, are described measurement and data evaluation of environment samples collected after Chernobyl's accident. This samples was measured with technique of gamma spectrometry in cooperation with Department of Nuclear Reactors on FJFI ČVUT. Important part of this work is determination of suitable radionuclide for this measurement. The goal of this measurement is not the area assignation of contamination with fallout, but determine degradation of fallout from environment.

Keywords

Gamma ray, Gamma spectrometry, Radionuclides, Fallout, Decay, Half-Life, Environment, Chernobyl accident.

Introduction

The reactor accident at the Chernobyl nuclear power plant was the worst in history, resulting in a severe nuclear meltdown. On 26 April 1986 at 01:23:40 a.m. reactor number four at the Chernobyl Nuclear Power Plant located in the former Soviet Union near Pripyat in Ukraine exploded. Further explosions and the resulting fire sent a plume of highly radioactive fallout into the atmosphere and over an extensive geographical area. Early after disaster, was the greatest health risk radionuclide 131I with half-life 8 days. Today are the worst fears from contaminated dirt with radionuclides 90Sr and 137Cs with half-life around 30 years. The greatests contaminations are in top levels of earth, where are absorbated with herbage, insects and mushrooms and getting this way to local food chain. It is likely that the main way to remove contamination from environment will be the native decay of radionuclide 137Cs into stable isotope 137Ba, because it turned out washing out with rain and surface waters like insignificant.

Gamma radiation

Gamma rays or gamma-ray (denoted as γ) are forms of electromagnetic radiation of a specific frequency produced from sub-atomic particle interaction, such as electron-positron annihilation and radioactive decay. Most are generated from nuclear reactions occurring within the interstellar medium of space. Gamma rays are generally characterized as electromagnetic radiation, having the highest frequency and energy, and also the shortest wavelength, within the electromagnetic radiation spectrum (high energy photons). Due to their high energy content, they are able to cause serious damage when absorbed by living cells.

Gamma spectrometry

Gamma spectroscopy is a radionuclidic measurement method. While a Geiger counter determines only the count rate, a gamma spectrometer will determine the energy and the count rate of gamma rays emitted by radioactive substances. Gamma spectroscopy is an extremely important method.

Most radioactive sources produce gamma rays of various energies and intensities. When these emissions are collected and analyzed with a gamma spectroscopy system, a gamma energy spectrum can be produced. A detailed analysis of this spectrum is typically used to determine the identity and quantity of gamma emitters present in the source. The gamma spectrum is characteristic of the gamma emitting nuclides contained in the source, just as in optical spectroscopy, the optical spectrum is characteristic of the atoms and molecules contained in the probe. The equipment used in gamma spectroscopy includes an energy sensitive radiation detector, a pulse sorter (multichannel analyzer), and associated amplifiers and data readout devices. The most common detectors include sodium iodide (NaI) scintillation counter and high purity germanium detectors.

Gamma decay

Gamma rays are often produced alongside other forms of radiation such as alpha or beta. When a nucleus emits an α or β particle, the daughter nucleus is sometimes left in an excited state. It can then jump down to a lower level by emitting a gamma ray in much the same way that an atomic electron can jump to a lower level by emitting visible light or ultraviolet radiation. Gamma radiation measured in this experiment is is type of gamma decay of cesium with 137 nucleons:

$$^{137}Cs \rightarrow {}^{137}Ba^{*} + e^{-} \rightarrow {}^{137}Ba + \gamma\ (661{,}66\ keV) \qquad (1)$$

The diagram shows beta decay of nucleus ^{137}Cs to excited nucleus of barium ^{137}Ba and emssion of an electron (beta radiation). The excitated nucleus release this energy in form of gamma photon with specific energy of 661,66 keV as is showen in fogure 1.

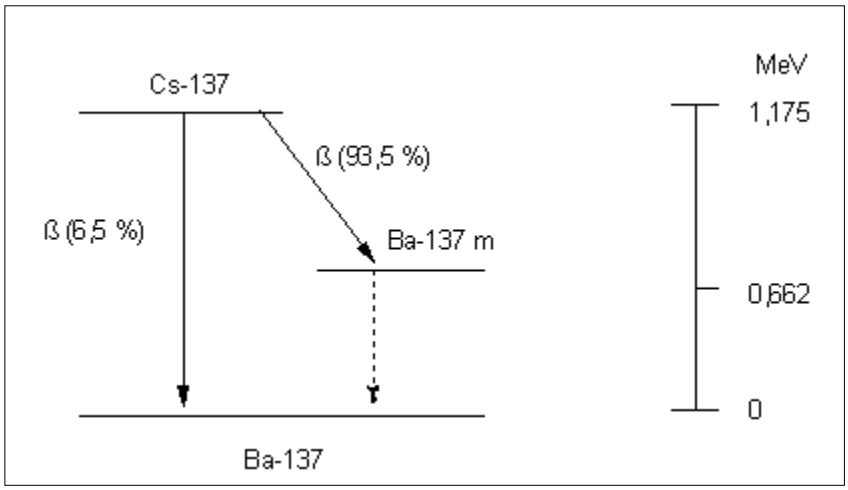

Figure 1. Decay of ^{137}Cs

Detector overview

The kinds of detectors commonly used can be categorized as:
A) Gas-filled Detectors
B) Scintillation Detectors
C) Semiconductor Detectors
The choice of a particular detector type for an application depends upon the X-ray or gamma energy range of interest and the application's resolution and efficiency requirements.

Scintilation detectors

A gamma ray interacting with a scintillator produces a pulse of light, which is converted to an electric pulse by a photomultiplier tube. The photomultiplier consists of a photocathode, one

focusing electrode and 10 or more dynodes that multiply the number of electrons striking them several times each. The anode and dynodes are biased by a chain of resistors. The properties of scintillation material required for good detectors are transparency, availability in large size, and large light output proportional to gamma ray energy. Relatively few materials have good properties for detectors. Thallium activated NaI and CsI crystals are commonly used, as well as a wide variety of plastics. $LaBr_3$ (Ce) crystals are a newer type of scintillation detector material offering better resolution, but otherwise, similar characteristics to NaI detector crystals. NaI is still the dominant material for gamma detection because it provides good gamma ray resolution and is economical. However, plastics have much faster pulse light decay and find use in timing applications, even though they often offer little or no energy resolution.

Semiconductor detectors

Semiconductor detectors have a p-i-n diode structure in which the intrinsic (i) region is created by depletion of charge carriers when a reverse bias is applied across the diode. When photons interact within the depletion region, charge carriers (holes and electrons) are freed and are swept to their respective collecting electrode by the electric field. The resultant charge is integrated by a charge sensitive preamplifier and converted to a voltage pulse with an amplitude proportional to the original photon energy.Since the depletion depth is inversely proportional to net electrical impurity concentration, and since counting efficiency is also dependent on the purity of the material, large volumes of very pure material are needed to ensure high counting efficiency for high energy photons. Just as Ge transistors have much lower maximum operating temperatures than Si devices, so do Ge detectors. As a practical matter both Ge and Si photon detectors must be cooled in order to reduce the thermal charge carrier generation (noise) to an acceptable level. This requirement is quite aside from the lithium precipitation problem which made the old Ge(Li), and to some degree Si(Li) detectors, perishable at room temperature. The most common medium for detector cooling is liquid nitrogen, however, recent advances in electrical cooling systems have made electrically refrigerated cryostats a viable alternative for many detector applications.In liquid nitrogen (LN2) cooled detectors, the detector element (and in some cases preamplifier components), are housed in a clean vacuum chamber which is attached to or inserted in a LN2 Dewar. The detector is in thermal contact with the liquid nitrogen which cools it to around 77 K. At these temperatures, reverse leakage currents are in the range of 10^{-9} to 10^{-12} amperes.

Instruments

The main question was, what kind of detector use. Available was two types of detectors, the scintillator NaI crystal and the gamma spectometer with HPGe detector. For this mesurement was chosen, with respect to see above, multichannel analyzer Canberra ACCUSPEC B with 16384 channels and semiconductor detector HPGe (High Purity Germanium) Canberra GC2518 with efficiency 20% and resolution 1,8 keV (per channel). Software for detection and data evaluation was program Genie v 3.1 in basic version.

Samples

The samples was collected within the range of years 1986 and 1988 in the locality N 4955', E 1328', near city Plasy north of city Pilsen, Czech Republic near river Střela. The samples are common forest fruits, in this case bilberries, mushrooms and vegetable (surface collection).

Procedure of measuring

Every sample was measured for 16 hours in measuring chamber with 50 millimeters thick shilding wall from lead slots to suppression of backgroun radioactivity. The background was measured of course too, to determine his supply to total count of detected gamma photons.

Results

In this time was measured three samples, in the concrete samples bilberries 86', vegetable 87' and mushrooms 88' in the order of years and other will be measured in future. Searched was significant amount of isotope ^{137}Cs in samples and in results is marked number of decays of this isotope (in fact gamma photons emited by ^{137}Ba) captured by detector. This results are shown in diagrams on figure 2.

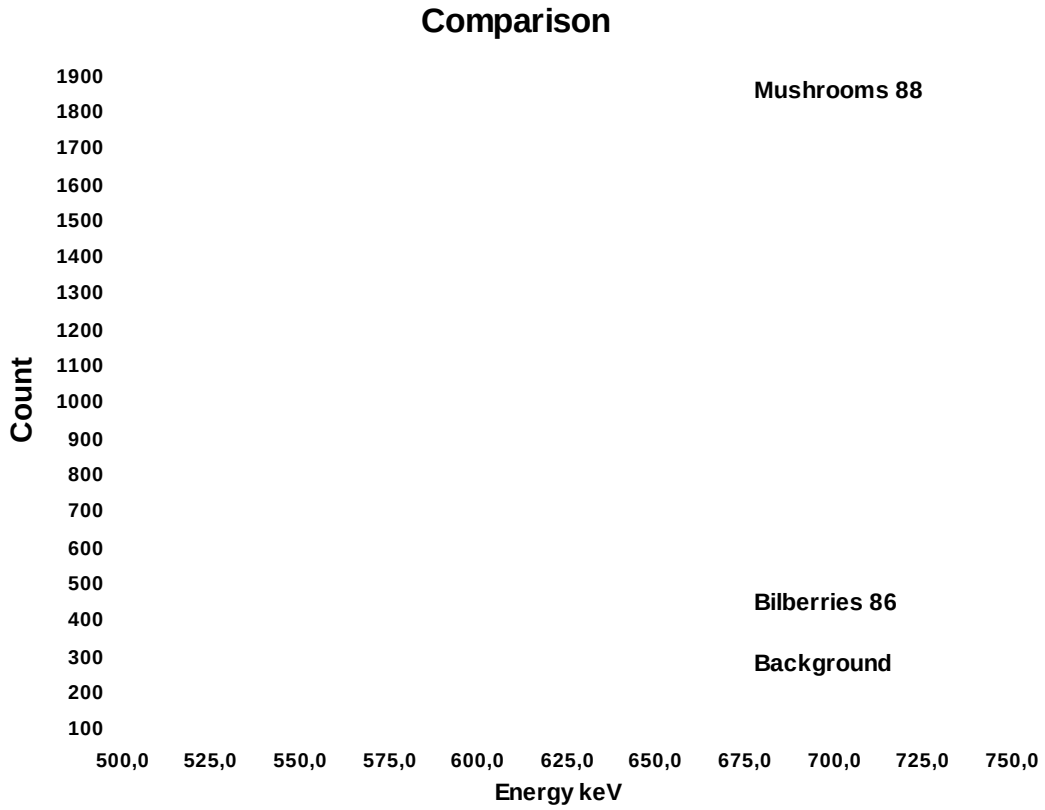

Figure 2. Comparison of ^{137}Cs decays in measured samples

As results from measured values, even past over twenty years was discovered significant marks of ^{137}Cs via gamma photons with energy 661,66 keV. This measurements will be further continue to determination relative amount and specific contant of radionuclides in samples from other years after Chernobyl's accident.

Literature

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